United States
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Agency

Risk Reduction
Engineering Laboratory
Cincinnati, OH 45268

Research and Development

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Project Summary

EPANET Users Manual

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EPANET is a third generation software package for modeling water quality within drinking water distribution systems. The program performs extended period simulation of hydraulic and water quality conditions within pressurized pipe networks. In addition to substance concentration, water age and source tracing can also be simulated. EPANET includes a graphical user interface that runs under Microsoft® Windows™ and allows simulation results to be visualized on a map of the network. EPANET is currently being used to study such water quality problems as chlorine decay dynamics, source blending, effects of altered tank operation on water age, and control of total dissolved solids control in reclaimed water used for irrigation.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

To meet regulatory requirements and customer expectations, water utilities have a growing need to understand better the movement and transformation undergone by treated water introduced into their distribution systems. Sampling alone often provides an incomplete picture of water quality dynamics within a system and is of limited help when contemplating changes in system design and operation. For these reasons, computerized simulation models are becoming popular and essential tools for tracking the fate of water and its quality transformations within distribution systems.

EPANET represents a third generation of public domain software developed by the US Environmental Protection Agency's Risk Reduction Engineering Laboratory for modeling water quality within distribution systems. The program performs extended period simulation of hydraulic and water quality conditions within pressurized pipe networks. It tracks the flow of water in each pipe, the pressure at each pipe junction, the height of water in each tank, and the concentration of a dissolved substance at each junction during a multi-time period simulation. In addition to concentration, water age and source tracing can also be simulated.

Typical uses for the EPANET model would include hydraulic calibration using chemical tracers (e.g., fluoride), design of sampling programs, chlorine decay analysis, evaluation of modified system operation (e.g., altered source utilization or tank operation), selection of satellite treatment locations, and use of targeted pipe cleaning and replacement to enhance water quality.

Program Features

The EPANET package actually consists of two programs. One performs the actual hydraulic and water quality simulations with

* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

the use of data files for input and output reports. The second program (EPANET4W) provides a graphical user interface for interactively running the simulator and viewing its results via network maps, data tables, and time series graphs.

Key features of the simulator include:

- modular, highly portable C language code with no pre-set limits on size of network,
- a simple data input format based on a problem oriented language,
- a full-featured, extended period, hydraulic simulator that can handle various types of pressure and flow regulating valves, both fixed and variable speed pumps, and either level- or timer-control rules on pump and valve operation,
- an improved and more efficient algorithm for tracking water quality changes over time throughout a network,
- the capability to consider water quality reactions both within the bulk flow and at the pipe wall.

The graphical user interface is written in Microsoft® Visual Basic™ and operates within the Windows™ 3.x environment on a personal computer. It allows one to edit EPANET input files, run a simulation, and view the results all within a single program. Simulation output can be visualized through:

- color-coded maps of the distribution system with full zooming, panning, and labeling capabilities and a slider control to move forward or backward through time,
- spreadsheet-like tables that can be searched for entries meeting a specified criterion,
- time series graphs of both predicted and observed values for any variable at any location in the network.

The last item proves to be an invaluable feature for network calibration.

Sample Application

Figure 1 displays a small example network that will be used to illustrate some of EPANET's features. Water is pumped into the network from a surface reservoir at Node 17 and from a well at Node 16. A tank at Node 15 provides water storage and flow equalization. Operation of the reservoir pump is tied to the level of water in the tank while the well is on a 12-hour-on, 12-hour-off pumping schedule. Nodal demands follow a typical 24-hour diurnal cycle. EPANET was used to analyze what percent of water reaching any node in the network throughout the day originates at the well.

Table 1 is an abridged version of the input data for this example. Note the liberal use of comments (text to the left of a semicolon) to make the input more readable and tabular in nature. In the [JUNCTIONS] section, the well is treated as a junction with a negative demand. In the [TANKS] section, Node 15 is a tank with a variable water level whereas Node 17 is treated as a reservoir with a fixed water level. The [PATTERNS] section supplies a set of 24 hourly multipliers by which the average nodal demands are adjusted during the day. By default, all nodes follow this pattern unless otherwise indicated. The [OPTIONS] section indicates that the file EXAMPLE.MAP contains X-Y coordinates and labels for the system map. It also requests that a trace of source water emanating from Node 16 (the well) be made. If a chemical analysis had been chosen instead, then additional input data sections would be used to specify initial concentrations throughout the network, concentrations in the source waters, and reaction rate coefficients.

Figure 2 shows what the Windows version of EPANET would look like after the input file has been opened. At this point the input data could be edited and then analyzed with the simulator. Figure 3 shows the display after a simulation has been made. The nodes and links on the map are actually color-coded to emphasize the different levels of the current view variable, which in this case is percent of water from the well at Node 16 (i.e., % N16). The Browser panel on the right of the display controls the node and link view variable, displays the current values of these variables for any node or link, and sets the simulation time. Any choices made in the Browser cause the map to be updated. Other variables besides water quality can also be viewed. These include demand, elevation, hydraulic grade, and pressure for nodes and diameter, flow, velocity, and head loss for links.

Figure 4 illustrates the creation of a time series graph for % of well water reaching Node 5. To generate this graph, one merely had to click the mouse on Node 5 on the map (or select it from the Browser) and select the Graph command from the menu across the top of the display. Another graphing option allows prerecorded data (from SCADA systems or field sampling) to be superimposed on a graph. This feature is especially useful for model calibration.

Figure 5 illustrates the creation of a table showing results for all nodes in the network at hour 12 of the simulation. The bottom of the display shows how a query was formed to search this table for all nodes where the flow from the well was above 50%. Similar kinds of queries can be done visually by modifying the map legend so that items meeting the search criterion appear in a particular color.

In addition to screen displays, EPANET can also print out the contents of any window or copy the contents to the Windows clipboard. The map in Figure 1 was printed directly from EPANET.

Current Uses

EPANET is currently being used to study a variety of water quality related issues in distribution systems. These include:

- chlorine decay dynamics,
- source blending and trihalomethane propagation
- the effect of altered tank operation on water quality and age
- control of total dissolved solids in blending reclaimed water with groundwater for irrigation.

The EPANET program should provide water managers with a useful tool for understanding and analyzing water quality behavior within distribution systems.

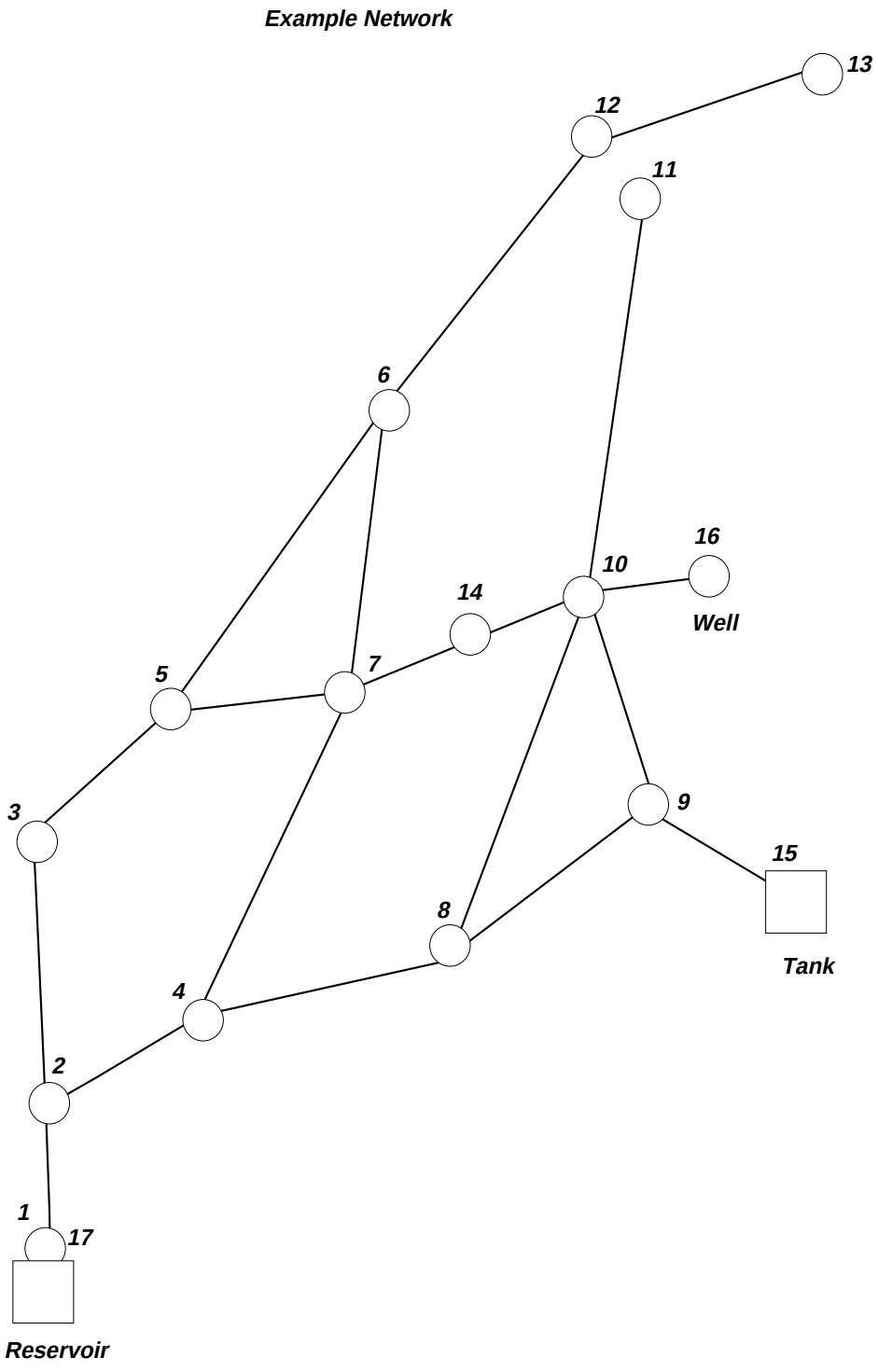

Figure 1. *Example water distribution network.*

Table 1. *Excerpt of EPANET input file.*

```
[TITLE]
EXAMPLE NETWORK

[JUNCTIONS]
;            ID            ELEV.         DEMAND      PATTERN
;-------------------------------------------------------------------------------
             1             340           0
             2             350           90
             3             360           70
             <Nodes 4 - 13 not shown>
             14            380           80
             16            380           -400          3             ;WELL

[TANKS]
;                                        INIT          MIN           MAX
;            ID            ELEV.         LEVEL         LEVEL         LEVEL         DIAM
;-------------------------------------------------------------------------------------------
             15            470           48            35            50            60
             17            340

[PIPES]
;            ID          NODE1       NODE2       LENGTH       DIAM       C-FACTOR
;-------------------------------------------------------------------------------------------
             1             1             2             1800          16            100
             2             2             4             1600          12            100
             3             2             3             2900          8             100
              <Remaining pipes not shown>

[PUMPS]
;            ID          NODE1       NODE2       HEAD         FLOW
;-------------------------------------------------------------------------------
             20            17            1             200           1000

[CONTROLS]
LINK 20 OPEN IF NODE 15 BELOW 42
LINK 20 CLOSED IF NODE 15 ABOVE 49

[PATTERNS]
;            ID          FACTORS
;-------------------------------------------------------------------------------------------
             1           1.0           1.6           1.5           1.4           1.2           1.2
             1           1.2           1.1           1.0           1.0           1.1           1.2
             1           1.3           1.2           1.1           1.0           1.0           0.8
             1           0.6           0.5           0.4           0.4           0.5           0.7
              <Remaining patterns not shown>

[OPTIONS]
             MAP         EXAMPLE.MAP
             QUALITY TRACE 16

[TIMES]
             DURATION 24

[END]
```

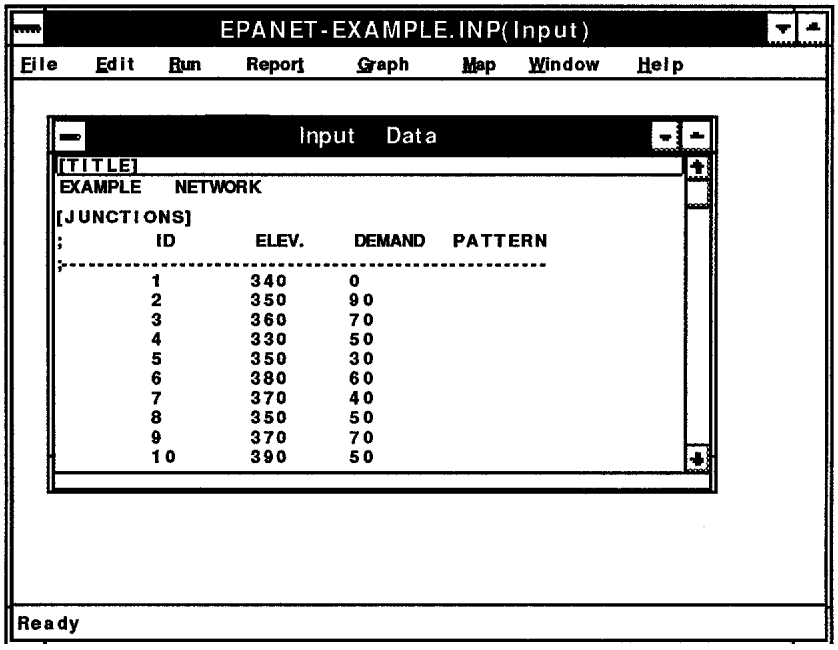

Figure 2. *View of example input data.*

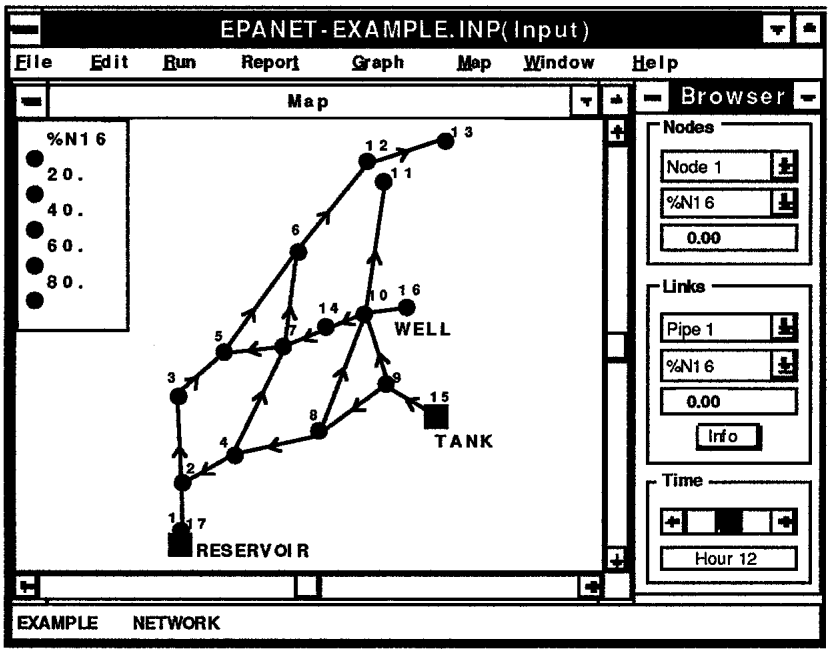

Figure 3. *View of network map and browser.*

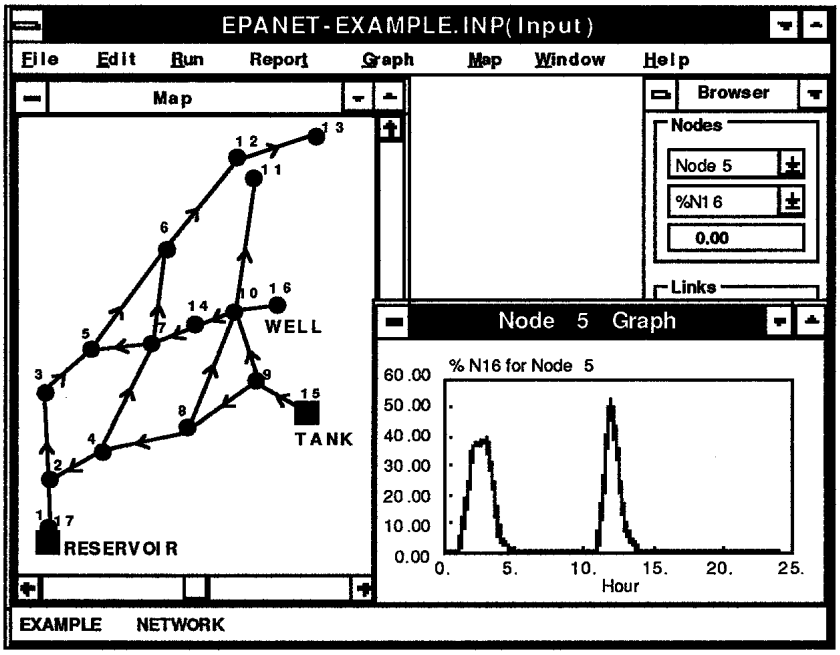

Figure 4. *Example time series graph.*

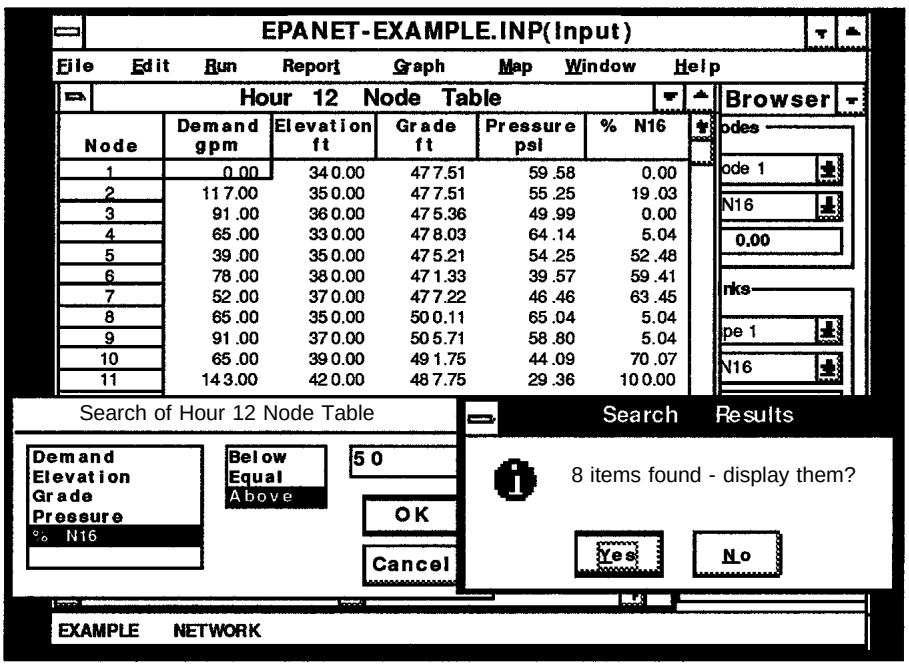

Figure 5. *Example table query.*

Lewis A. Rossman *(also the EPA Project Officer) is with the U.S. Environmental Protection Agency's Risk Reduction Engineering Laboratory (see below).*

The complete report consists of a manual and diskette.
Manual—(Order No. PB94-165610AS; Cost: $27.00, subject to change)
Diskettes & Manual—(Order No. PB94-501673/AS; Cost: $90.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
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The EPA Project Officer can be contacted at:

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